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DEVELOPMENTAL PLAN FOR THE DESIGN, DEVELOPMENT, AND PRODUCTION OF A SPACE PROBE ALTIMETER

Final ~~Technical~~ Report

Volume 2 ~~of 3~~

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Prepared under Contract ~~No.~~ NAS 1-5954 by
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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This is volume two of a three volume set of documents comprising the final report of a study to define the design of a space probe altimeter. The documents of this series include the following:

1. Design
    a. Detailed Conceptual Design
    b. Drawings
    c. Growth Potential
2. Developmental Plan
    a. Project Planning Network
    b. Manufacturing Plan
    c. Environmental Tests Program Plan
    d. Flight Test Qualification Plan
    e. Facilities Plan
    f. Project Funding Plan
3. Reliability and Quality Assurance Plan
    a. Reliability and Quality Assurance
    b. Predicated Effects of Sterilization

This study was conducted by Texas Instruments Incorporated Apparatus Division for the National Aeronautics and Space Administration, Langley Research Center, Langley Station, Hampton, Va., under contract number NAS 1-5954, from March 1966 to November 1966.

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SUMMARY

This report contains the developmental plan which encompasses the project planning network, manufacturing, environmental tests, flight test qualifications, facilities, and project funding.

Manufacturing will be on a model shop basis or will be done in a short-run production facility within the main fabrication shop. The assembly and testing of the altimeter will be conducted in a horizontal laminar flow clean-room. For additional testing, government facilities will be required to perform certain tests for which facilities are not available at Texas Instruments, or for tests which require testing in conjunction with other assemblies and/or the Probe/Lander itself.

For flight test qualifications it has been shown that a balloon drop is the most feasible method for additional tests of the altimeter. Other test facilities at Texas Instruments are discussed in this report and a budgetary estimate of the cost of developing, testing, and delivering a maximum of ten radar altimeters has been made.

INTRODUCTION

The developmental plan for construction of MERA radar altimeters is included in this report. A bar graph and project planning network outline major tasks to be performed to successfully complete this program on schedule. A contract award date of July 1967 was assumed.

Figure 1 shows primary program phases (design, test and production) in a simple bar graph with a linear time scale. Major program tasks are also shown, with significant milestones. This schedule coincides with the development of the required MERA components for this program.

Figure 2 is a planning network generated in sufficient detail to identify all major design, test, documentation and support tasks required to complete the program. This chart is not on a linear time scale for reasons of space, but important events are dated. Major features of this plan are:

1) Reliability Program. - Reliability and quality assurance efforts start at the beginning of the program and are not complete until the first mission is complete. Volume 3 provides complete details of this effort.

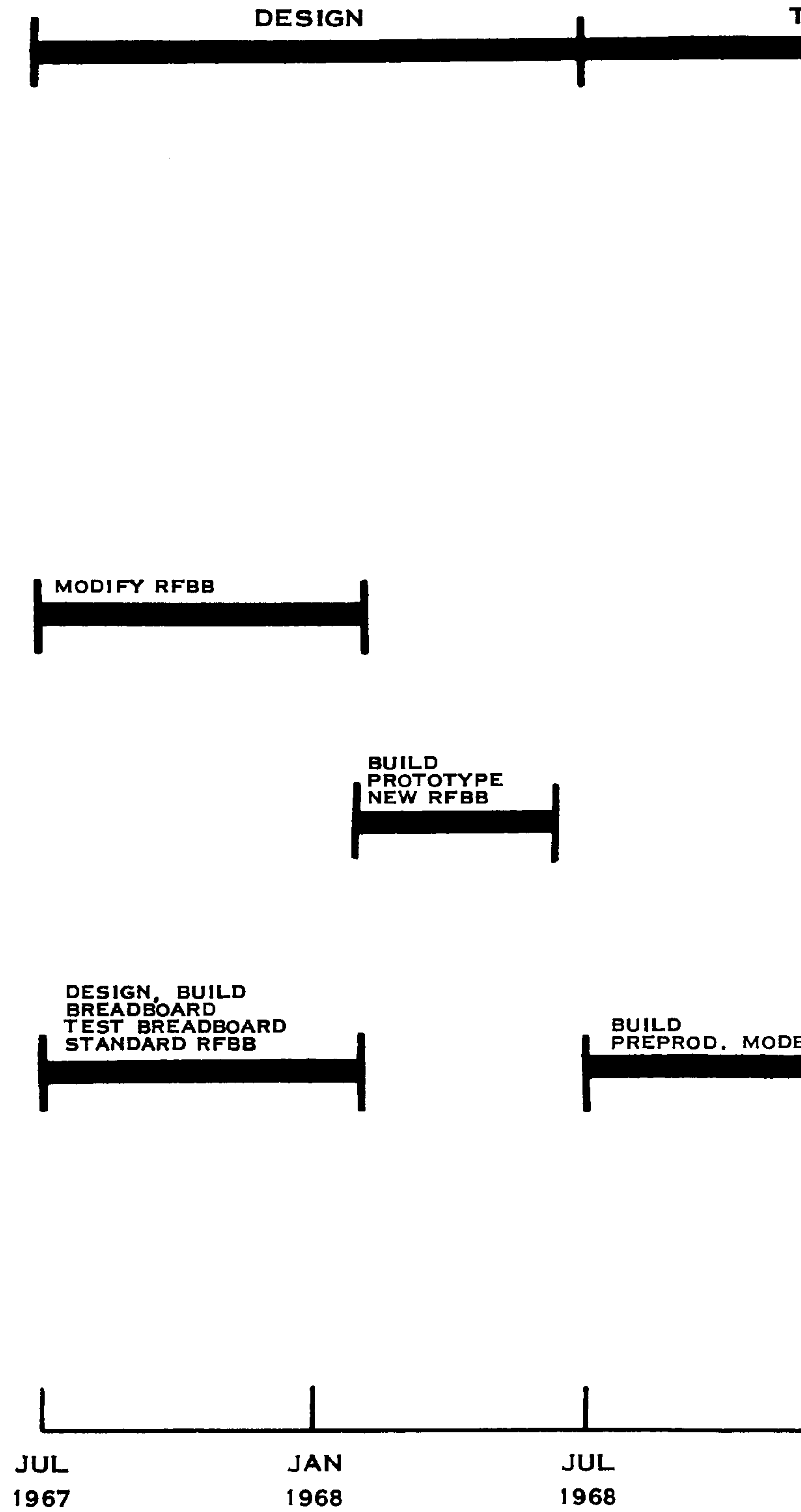
2) Breadboard. - A bench operating altimeter will be constructed to completely define electrical interface problems and to familiarize project personnel with the complete system.

3) Prototype. - A prototype, or "flyable breadboard" allows definition of mechanical interfaces and the development of manufacturing drawings. This unit will be operable, but is not expected to meet all environmental conditions or to be sterile.

4) Preproduction Model. - This model will be built to the drawings developed in the prototype phase. This model will meet all environmental conditions and will be used in environmental testing. After successful completion of tests, the production drawings can be finalized.

5) Production. - Additional units can now be constructed to firm drawings and delivered according to a firm schedule.

6) Support. - Prelaunch and landing support are listed, which include aid in final testing, etc.


DESIGN
MODIFY RFBB
BUILD
PROTOTYPE
NEW RFBB
DESIGN, BUILD
BREADBOARD
TEST BREADBOARD
STANDARD RFBB
BUILD
PREPROD.
JUL
1967
JAN
1968
JUL
1968

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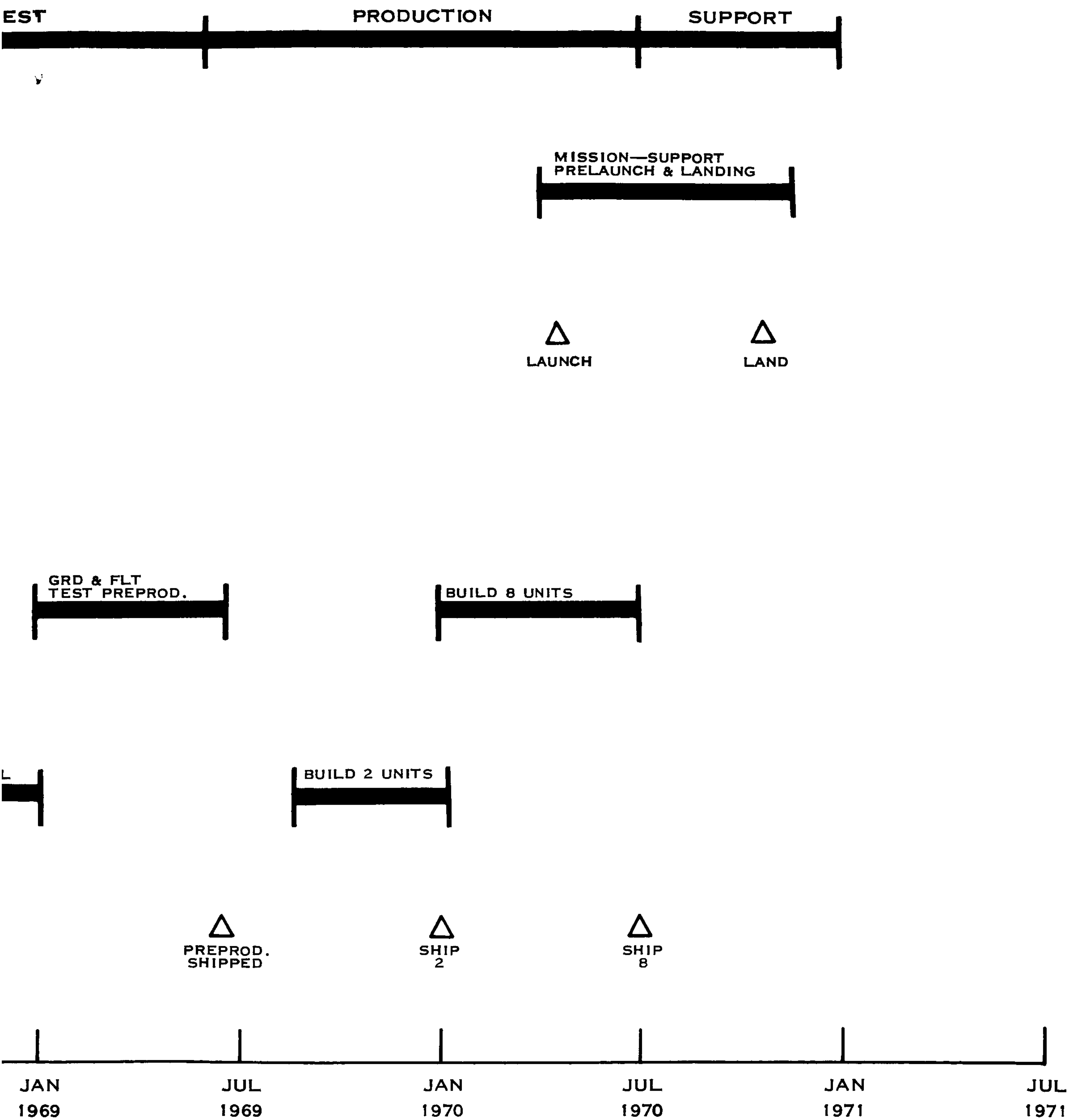
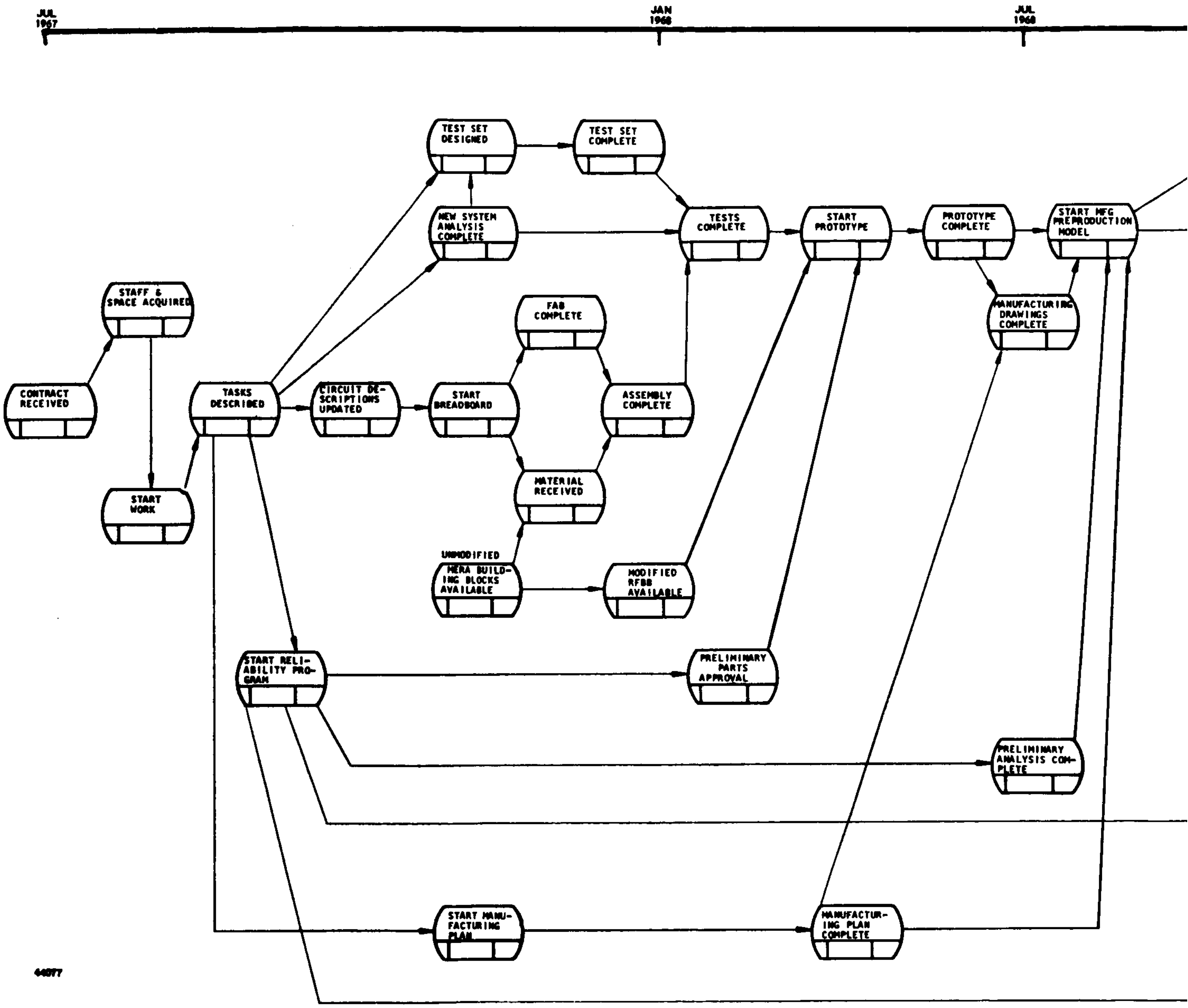


Figure 1. Development Plan/Milestone Scale


JUL 1967
JAN 1968
JUL 1968
TEST SET DESIGNED
TEST SET COMPLETE
NEW SYSTEM ANALYSIS COMPLETE
TESTS COMPLETE
START PROTOTYPE
PROTOTYPE COMPLETE
START MFG PREPRODUCTION MODEL
STAFF & SPACE ACQUIRED
MANUFACTURING DRAWINGS COMPLETE
FAB COMPLETE
CONTRACT RECEIVED
TASKS DESCRIBED
CIRCUIT DE-SCRIPTIONS UPDATED
START BREADBOARD
ASSEMBLY COMPLETE
START WORK
MATERIAL RECEIVED
UNMODIFIED
MERA BUILD-ING BLOCKS AVAILABLE
MODIFIED RFBB AVAILABLE
START RELI-ABILITY PRO-GRAM
PRELIMINARY PARTS APPROVAL
PRELIMINARY ANALYSIS COM-PLETE
START MANU-FACTURING PLAN
MANUFACTUR-ING PLAN COMPLETE
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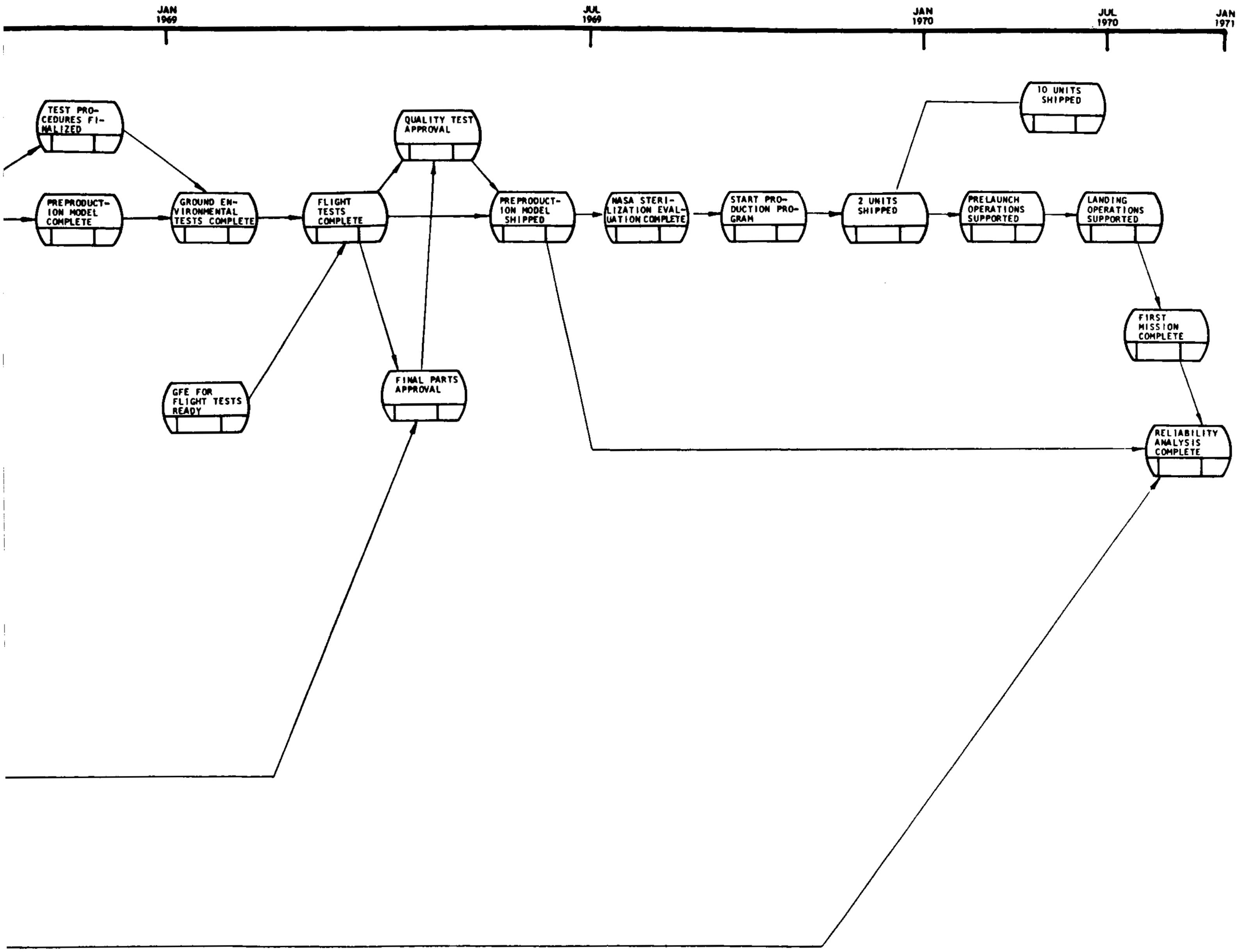

Figure 2. Developmental Planning Network (PERT)

MANUFACTURING PLAN

Tooling Plan

The present configuration of the radar altimeter utilizes a base that can be fabricated as a casting or a dip-brazed assembly. Because of the small quantities involved, the dip-brazed type construction seems preferable and would require much less complex tooling to fabricate. All components are of the type that are currently being produced at Texas Instruments and will not require special unique tooling. Due to the small quantities involved, all parts would be produced on a model shop basis with highly skilled machinists (model makers) performing the actual work. Texas Instruments has a complete, modern fabrication facility that has been engaged in aerospace production for several years. All equipment in this facility is company-owned and no additions of government-owned machine tools are foreseen.

During the design phase, parts will be evaluated for producibility and tooling will be developed along with the parts to ensure repeatability of fabrication and the highest possible quality in the end item.

Production Plan

As previously mentioned, due to the limited quantity involved, parts will be fabricated on a model shop basis or in a short-run production facility within the main fabrication shop. These shops are staffed with the more highly skilled machinists who are capable of producing highly complex parts with minimum tooling. Fabrication of parts for the engineering model will be monitored and the required changes, along with improvements, will be incorporated in the design prior to production of the flight units.

The manufacturer of the RF building block will utilize the most recent developments in transistor, diode and thin-film technology. Cleanrooms are to be utilized in the areas of photo masking, etching and evaporation of the thin film.

At the present time all of the required electrical test equipment is on hand with the exception of a custom design altimeter test set which will be produced prior to the completion of the radar altimeter.

Assembly Plan

The design of the altimeter lends itself readily to assembly. The RF building block will be assembled in a clean area and after completion of final tests, will be hermetically sealed in an inert (nitrogen) atmosphere. The several functional modules will be assembled and tested prior to installation into the altimeter. All of the component parts are of the type that have previously been assembled at Texas Instruments for spacecraft application, except for the radiating element which incorporates the RF building block. The construction of this unit requires permanent connections of all parts rather than plug-in assemblies, and a progressive assembly test procedure will be formulated to ensure that all of the components are functioning properly as they are installed. At each stage of assembly, the unit will be tested prior to continuing to the next level.

A prefabricated wiring harness will provide all of the interconnections between the various functional assemblies. The design of the unit allows for easy access to each box for connection to the harness. As each module is assembled to the unit, it will again be tested to ensure a reliable connection.

The assembly and preliminary testing of the altimeter will be conducted in a horizontal laminar flow clean room, which exceeds the requirements of Federal Standard No. 209, Class 100, 000. The closely controlled environment will greatly reduce the probability of entrapment of bacteria and microorganisms. The assembly and test procedures will be developed for minimum contamination after final sterilization.

ENVIRONMENTAL TEST PROGRAM PLAN

Summary

Exact conditions for environmental testing of the altimeter at a systems level have not been precisely defined. The environments listed in this report are expected to be closely representative of the actual testing conditions to be delineated by firm specifications written for a subsequent development program. A table of environmental tests is included, which lists expected test levels for various altimeter assembly type approval and flight approval tests.

Environmental Test Plan

The RADAR ALTIMETER will be subjected to the assembly-level environmental tests as indicated by Table I. These tests consist of type approval, flight approval, and life testing. The test and the expected levels thereof are listed and are based upon available information and specifications (references 1, 2, 3) applicable to the flight mission. Due to the lack of lander details and other environment information, the levels for several tests have been omitted and it is assumed that the detailed equipment specification will include this information. The effort to perform the testing per Table I, has been included in the costs specified elsewhere.

It is planned that the use of the government facilities will be required to perform certain tests for which facilities are not available at Texas Instruments, or for tests which require testing in conjunction with other assemblies and/or the Probe/Lander itself. This requirement is shown in Table I.

Table 1. Radar Altimeter—Environmental Test Plan

Seq	Test	Test Level	Remarks	Facility
Assembly Level Type Approval Tests—				
1	Bench Handling Shock	MIL-STD-810A, Method 516 Procedure VI		Texas Instruments
2	Transportation Shock	6 drops from 42-inch height	Ref: IV. E, Para 2 and Table 3 JPL Project Document 92 Unit to be packaged in suitable shipping container during test	Texas Instruments
3	Transportation Vibration	0.9 g Peak 2-35 cps 2.0 g Peak 35-48 cps 3.5 g Peak 48-500 cps	Ref: IV. A, JPL Project Document 92 Unit to be packaged in suitable shipping container during test	Texas Instruments
4	Explosive Atmosphere	MIL-STD-810A, Method 511, Procedure I		Texas Instruments
5	Humidity	95% Relative Humidity for 1/2 hour	Ref: Par 4.2.2, JPL Spec 30250B	Texas Instruments
6	RF Interference	As Specified in detailed spec	Ref: JPL Specs 30250B, 30236 and JPL Project Document 92	
7	Pyrotechnic Shock	5 (200g), 0.5 to 1.0 millisecond terminal peak sawtooth shocks in each of 3 axes	Ref: JPL Project Document 92	Texas Instruments
8	Static Acceleration	±14g, 3 axes for 5 minutes	Ref: JPL Project Document 92	Texas Instruments
9	Vibration—Low Frequency	±1.5 inches, 1 to 4.4 cps, 3g peak, 4.4 to 15 cps, Time duration 3 minutes each axis	Ref: JPL Spec 30250B	Texas Instruments or Government
10	Vibration—Complex Wave	a. 0.2 g^2/cps from 300 to 1000 cps with 6 dB per octave roll-off from 1000 to 2000 cps. 3 dB per octave roll-off from 300 to 20 cps. 24 dB per octave roll-off below 20 cps and above 2000 cps. Time duration —3 minutes each axis. b. 5.0g rms noise plus 2.0g rms sine wave between 15 to 40 cps 9.0g rms sine wave between 40 to 2000 cps. Time duration —10 minutes each axis.	Ref: JPL Spec 30250B	Government

Table 1. Radar Altimeter—Environmental Test Plan (Continued)

Seq	Test	Test Level	Remarks	Facility
11	Thermal-Vacuum			
	a. Launch Simulation	a. Pressure reduced from 760 mm Hg to 76 mm Hg within 3 minutes or less then to -10^{-4} mm Hg	Ref: JPL Spec 30250B Note: Tests to be conducted with unit mounted in heat control system to simulate Probe/Lander environment.	Government
	b. Cruise Simulation	b. Reduce temperature to -10°C at 10^{-4} mm Hg pressure. Equipment to operate intermittently 1 hour on 1 hour off for a 4-hour interval. Raise temperature to +75°C. Operate equipment 1 hour in each 4-hour period for a total of 12 days.		
	c. Entry Simulation	c. To be specified by detailed spec.		
Assembly-Level Flight Approval Tests				
1	Vibration	To be specified by detailed spec. Similar to Type Approval test, but modified to simulate Probe/Lander environment.	Ref: JPL Project Document 76	Government
2	Thermal-Vacuum	To be specified by detailed spec. Similar to Type Approval test, but modified to simulate Probe/Lander environment	Ref: JPL Project Document 76	Government
Life Test				
	9 Month Life Test	Duration and test parameters to be specified by detailed spec. Test to be run in conjunction with testing of other Probe/Lander assemblies.	Ref: JPL Project Document 76	Government

FLIGHT TEST QUALIFICATION PLAN

Summary

An attempt to devise a simulated flight test for the Martian lander is contained in this report. After analyzing several methods of flight tests including a plane drop, a balloon launch, and a sounding rocket, it was shown from a cost and operational standpoint, that the balloon drop was the most feasible method of testing the altimeter. The plane drop and sounding rocket tests fall short of meeting the required test parameters, that is, at a descent altitude of 50 000 feet, the velocity must be 3000 meters per second and the flight vector must make an angle of 30 degrees with the horizontal. One particular unresolved problem is selection of the best radome material for use during the re-entry phase. This material must protect the altimeter and the other test package circuitry from the aerodynamic heating and at the same time be transparent to x-band microwave radiation. The nose cone must also present a fairly low drag coefficient for the test rocket so that the desired velocities can be obtained.

Introduction

Flight qualification of the Mars radar altimeter requires a simulated planetary re-entry. This simulation is to be achieved by placing the altimeter test package in a trajectory such that at an altitude of 50 000 feet, its velocity is 10 000 ft/sec at an angle of 60 degrees with the vertical. While this condition is not an exceptionally severe one from an aerodynamic heating standpoint, it does correspond to a free stream stagnation temperature of 6900°R. Since the heat transfer to the test package nose cone is approximately proportional to the difference between this value and the test package wall temperature, the design of the thermal protection system will be an important part of the package design.

In order to achieve the desired velocity at 50 000 feet with the most economical rocket motor, it is necessary to use the smallest physically realizable drag coefficient (C_D). A C_D of 0.1 was assumed in the trajectory analysis. Conflicting with this requirement is the desirability to provide the nose cone with the greatest possible radius of curvature because stagnation heat transfer due to convection is inversely proportional to radius of curvature. Such a nose cone would give a drag coefficient of unity and an overall drag coefficient greater than one because of the friction drag of the afterbody. The only compromise available is to use an ogival nose cone which provides minimum drag with a rounded tip. The radius of the tip would be maximized subject to the condition that C_D be less than or equal to 0.1.

Since the test package nose cone must be transparent to radiation at x-band frequencies, the use of a metallic heatsink—conduction—reradiation type of thermal protection is immediately ruled out in favor of an ablative protection technique. The most efficient of the ablation materials are the char forming resins exemplified by phenolic nylon. Upon exposure to a large heat flux, this material forms a highly refractory char layer that can sustain a high surface temperature while the virgin material serves as a good insulator. This char layer, however, has been found to seriously attenuate radio frequencies. According to a NASA technical report by Dow and others[4], phenolic nylon char attenuated 950 MHz to a level of 30 dB. Attenuation of this magnitude will not be acceptable. A number of ablative materials are available which are reasonably transparent at x-band frequencies. Due to the interaction of the nose cone thermal, structural, and dielectric properties, a final material selection will be made concurrently with the optimization of the trajectory, nose cone shape, and payload configuration.

At the velocities encountered in this test, the gas between the bow shock front and the nose cone, while it is hot enough for oxygen dissociation to begin, is not nearly hot enough for ionization. The bow shock will therefore not interfere with transmission of radio frequency energy.

Theoretical models for heat transfer between moderately high temperature bow shock layers and subliming or charring ablators are well known and are sufficiently accurate for nose cone design. Velocities are low enough so that heat transfer by radiation from the shock layer to the nose cone may be neglected and also the degree of dissociation is small enough so that this may be neglected without significant error. The boundary conditions of the convective gas boundary layer and those of the nose cone may be matched at the ablating surface by the method developed by Roberts[5]. This technique will allow calculation of surface temperature of the nose cone and temperature distribution in the virgin material. The second requires the choice of an ablative material which is transparent to radio frequencies. In summary it appears that the emphasis of thermal design will rest on two major areas. One involves the determination of a nose cone profile that provides the required low drag coefficient while keeping stagnation point heat transfer as low as possible. The other major area of design effort lies in the selection of an ablative material that provides the needed thermal protection and is also relatively transparent at x-band frequencies.

Flight Test Plan

The purpose of the flight test plan, which will be conducted in the earth's atmosphere, is to simulate worst-case entry into the Martian atmosphere. Since the density of Earth's atmosphere is, in general, much greater than that of Mars, the entry profile of the capsule into Earth's atmosphere will be

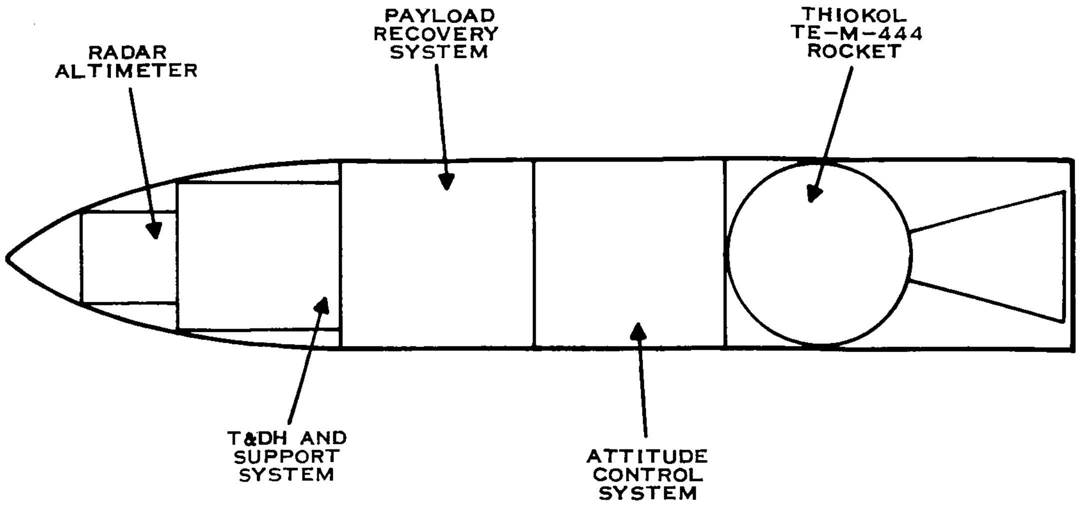

Figure 3. Sounding Rocket Configuration

considerably different than that of a Martian entry. The flight test plan requirement is to produce a velocity of 9840 ft/sec (3 Km/sec.) at an angle of 60 degrees to the vertical at 50 800 feet (15.5 Km). Three possibilities were investigated for obtaining this altitude-velocity requirement with the conclusion that a balloon drop followed by a solid rocket burn would be the simplest and most reliable method of meeting the test plan requirement.

The test plan contains an analysis of the various test methods, an outline of the supporting payload requirements, a review of the heating problem, and a statement of the compatibility of the WSMR supporting equipment with the data rates of the payload. The test method consideration received emphasis because of the critical cost and performance factors.

Test Method Considerations.— Three test methods were investigated. These were: sounding rocket launch, aircraft launch, and balloon launch. Each was followed by a solid rocket burn.

The configuration for a sounding rocket launch is shown on Figure 3. The attitude control system and recovery package are those normally supplied with the Aerobee 150 sounding rocket system. The Thiokol TE-M-444 booster was chosen so that it would fit within the nominal 15-inch payload envelope of the Aerobee 150.

The costs of the system as shown is 93 000 dollars for the purchased items:

$ 4 000	Recovery System
16 000	TE-M-444 Rocket
33 000	Aerobee 150
40 000	Attitude Control System
$93 000	

The sequence of events in the sounding rocket launch—re-entry would be as follows. The Aerobee 150 would be launched at an 80-degree angle from the horizontal (80 degrees is the limiting angle due in part to the launch tower structure and in part to the aerodynamic heating of the fin leading edges). This angle should be minimized in order to provide approximately 3000 ft/sec horizontal speed at apogee, which would be difficult if not impossible to achieve. At apogee, the altitude control system would stop the spin, reorient the vehicle, then re-spin in a new direction for final burn. As the vehicle approaches the atmosphere, the payload, altitude control system, and recovery system would separate from the Aerobee 150. The solid motor would then fire to produce a total horizontal velocity of 9000 ft/sec. As soon as the package reaches equilibrium velocity the empty rocket motor and attitude control system would be jettisoned. Immediately thereafter the recovery system will be deployed to bring the system to a soft landing. The range required for this launch is in excess of 300 miles, which is within the capability of White Sands Missile Range (WSMR).

Figure 4a and b shows a typical curve of the velocity vs altitude for this entry. Note the region of high deceleration in the region beginning at 70 000 feet.

Figure 5 shows the angle between the re-entry package velocity vector and the horizontal. Due to the high vertical velocity component, the desired angle of 60 degrees is not achieved. This is because the vertical velocity generated by gravity in falling from the apogee of the Aerobee is large compared to the horizontal component. It is assumed that the Aerobee was launched at the 80-degree angle, and a range rate of 2540 ft/sec was obtained at apogee; this was followed by a 5041 ft/sec component of range rate obtained from the solid rocket motor. A larger solid motor might be used to obtain the desired range rate, but this would exceed the 15-inch payload envelope available with the Aerobee 150; a development program required to adapt the payload envelope for a 20-inch motor would be too costly. In conclusion it was determined that a 60-degree angle from the vertical at re-entry is not feasible at 50 800 feet altitude with the desired entry velocity.

The configuration for an aircraft launch consists of a Thiokol TE-M-442 booster, an Aerobee 150 recovery package, plus the payload. This simple configuration has a total cost of purchased items of 34 000 dollars: 4 000 dollars for the recovery system and 30 000 dollars for the solid stage. The chronology of an aircraft launch begins with a drop from an aircraft in a pitched up attitude at an altitude of 53 000 feet. The solid rocket motor would drop to a minimum altitude of 52 000 feet for safety purposes. Rocket ignition would occur in an attitude such that it gains altitude to experience lower drag. The trajectory then arcs over ballistically so that the re-entry package approaches the atmosphere making a 60-degree angle with the vertical.

Figure 6 shows the results of a computer simulation indicating the velocity as a function of altitude for the airplane drop. Figure 7 shows a simulation of velocity angle with respect to the horizontal as a function of altitude. Note that the total velocity achieved meets the specifications of the flight test. The angle achieved at 50 000 feet is far too small. From the two velocity curves shown, it is obvious that a launch at any higher initial angle will produce a lower velocity and that a launch at any lower angle will produce a lower final angle at 50 000 feet. If the aircraft could carry the payload to an altitude above 70 000 feet or if a much heavier and more costly solid booster (such as the Surveyor main Retro-Rocket) were employed at 52 000 feet, a higher angle could be achieved. However, for a solid rocket such as is described, it is not possible to achieve the requirements of the test specifications.

The configuration for the balloon launch is shown on Figure 8. Note that the only difference between this configuration and that used in the aircraft launch is the balloon and associated control system which would be built by Texas Instruments. The solid stage is the TE-M-442 discussed previously and the recovery system is that used on the Aerobee 150. The balloon is a 3-million cubic foot capacity balloon manufactured by Schjeldahl. The cost of this system is itemized as follows:

\$25 000.00	Balloon
4 000.00	Recovery System
30 000.00	Booster
\$59 000.00	

The sequence of events for the balloon launch would be as follows. The thrust line, being preset in elevation on the ground, would be aligned in azimuth at 85 000 feet by a small azimuth control unit using the Earth's magnetic field as a sensor and gas jets as actuators. The re-entry vehicle would be released between 85 000 and 90 000 feet and the solid stage would immediately ignite and burn for 17.5 seconds. As soon as the vehicle reaches equilibrium velocity the rocket motor will be jettisoned and the recovery

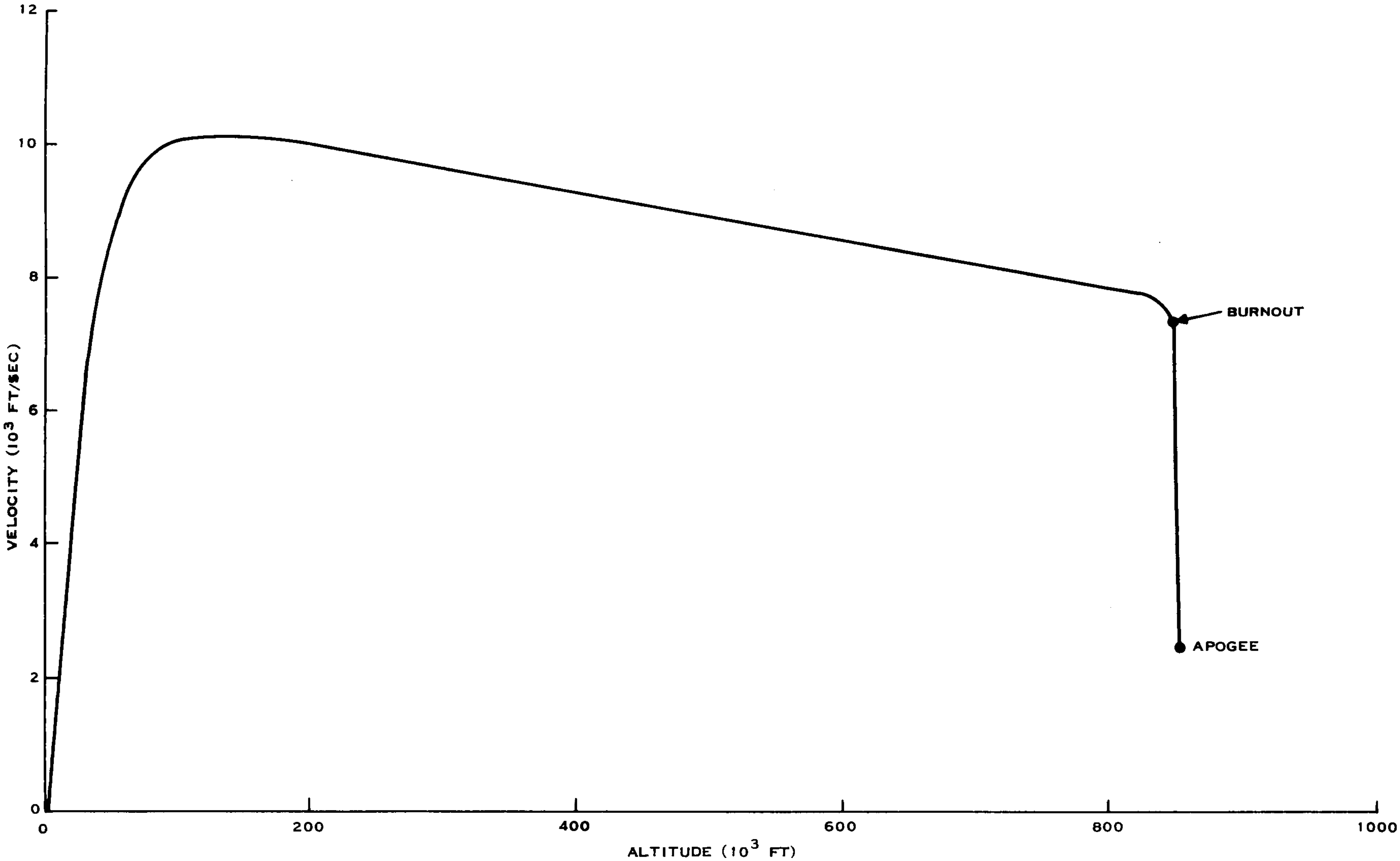

Figure 4a. Sounding Rocket Velocity Vs Altitude (Sheet 1 of 2)

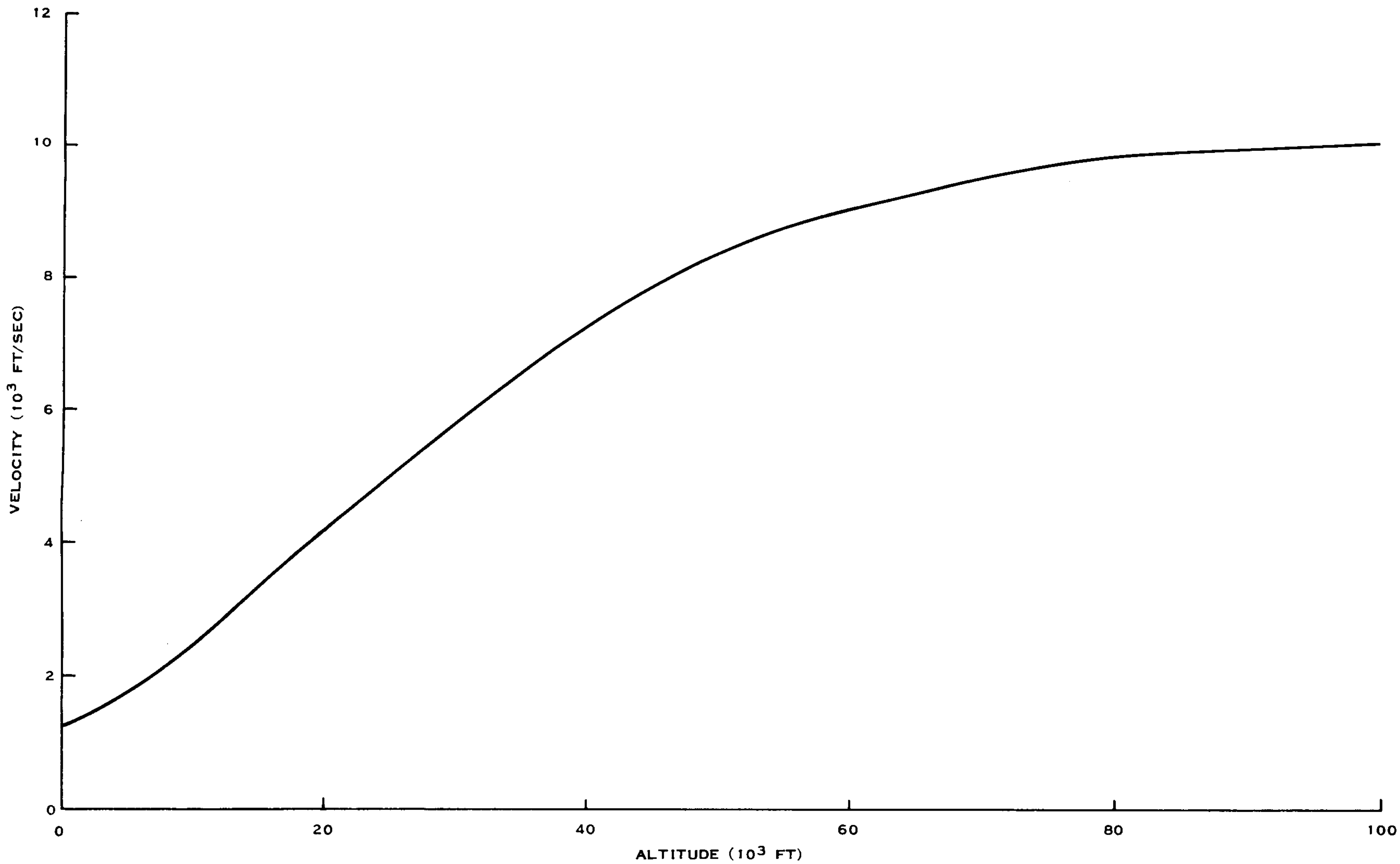

Figure 4b. Sounding Rocket Velocity Vs Altitude (Sheet 2 of 2)

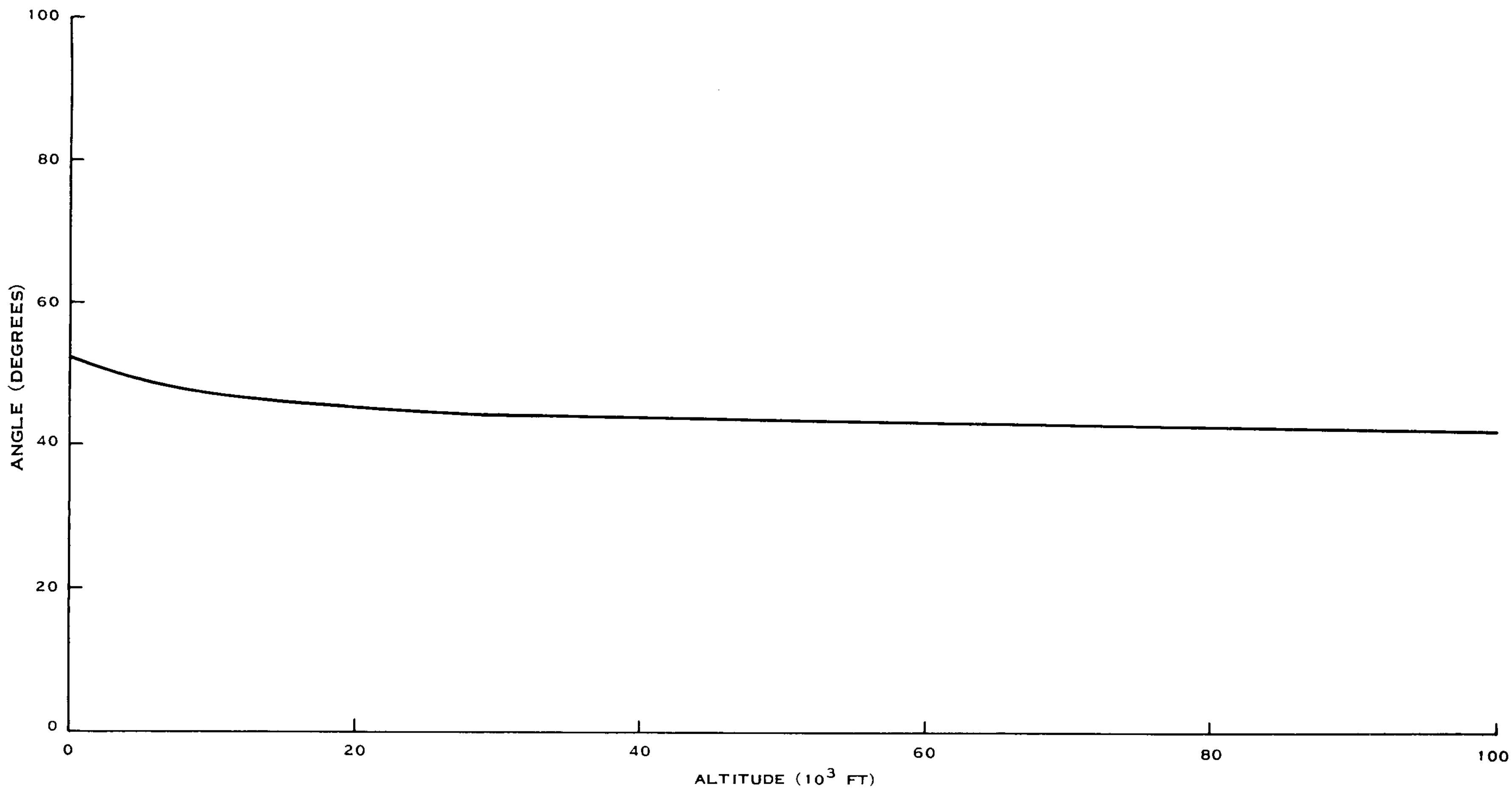

Figure 5. Sounding Rocket Angle Between Thrust Vector and Horizontal Vs Altitude—Descent Portion

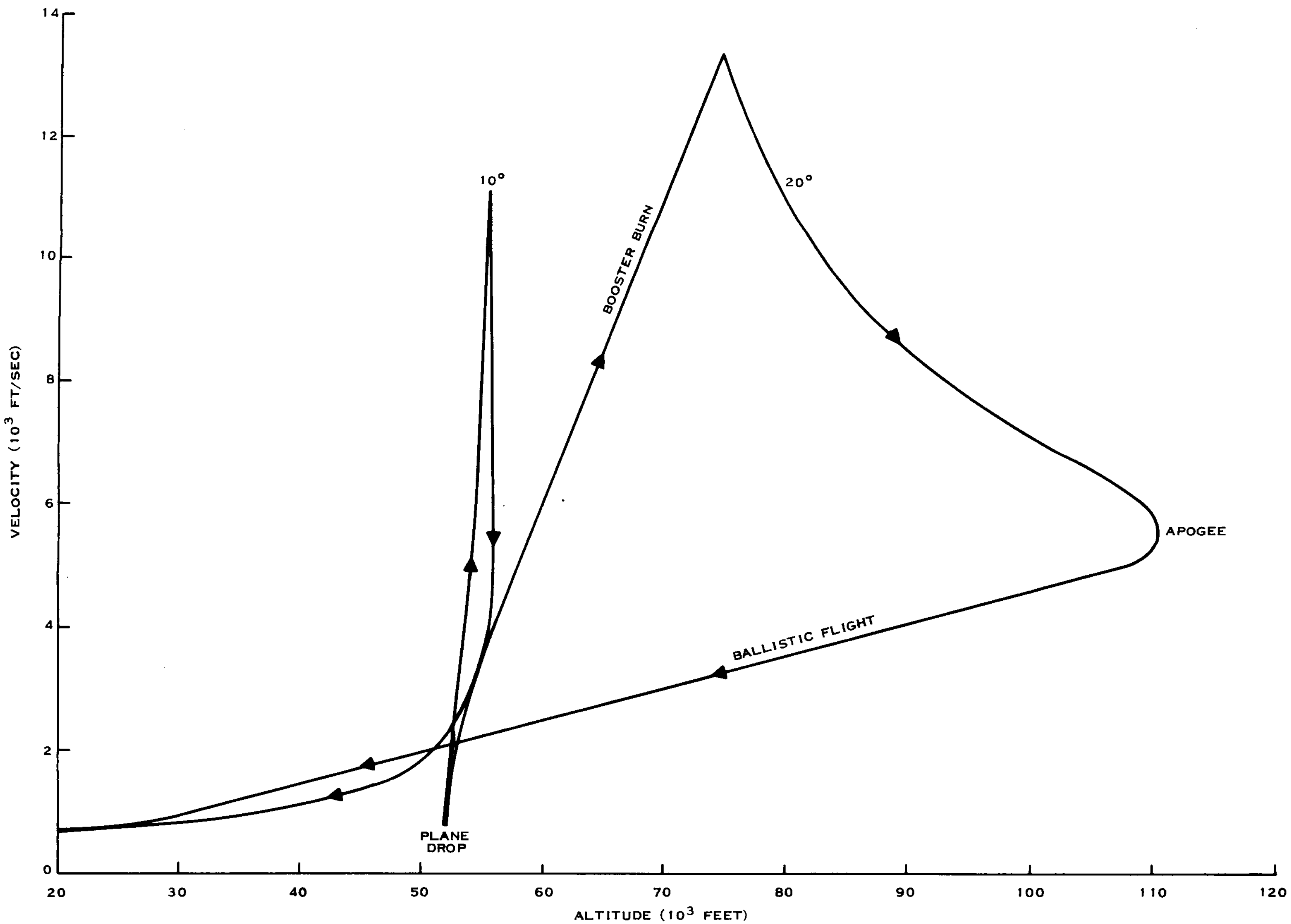

Figure 6. Aircraft Drop Velocity Vs Altitude

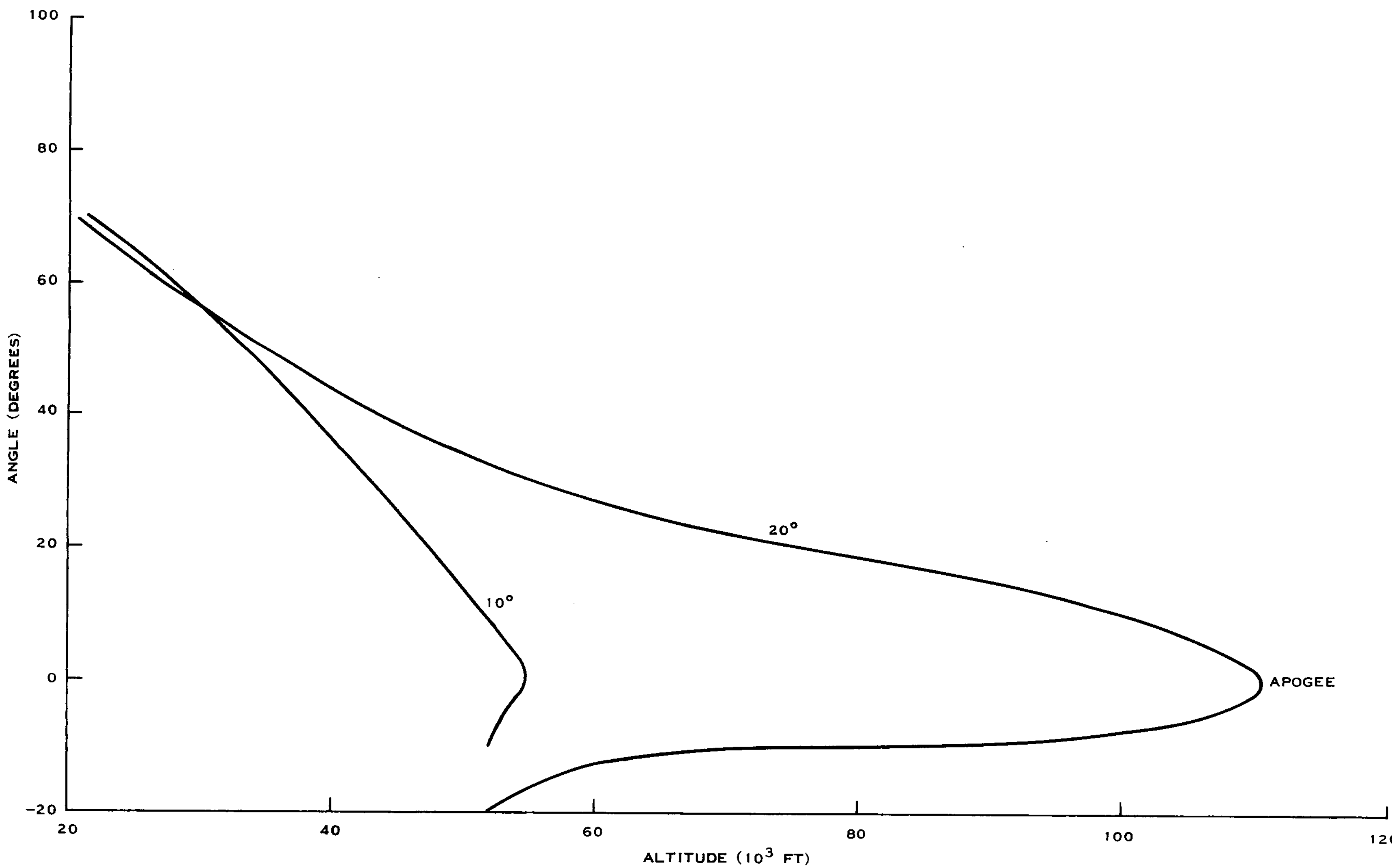

Figure 7. Aircraft Drop Angle Between Velocity Vector and Horizontal—Two Drop Angles Vs Altitude—Descent Portion

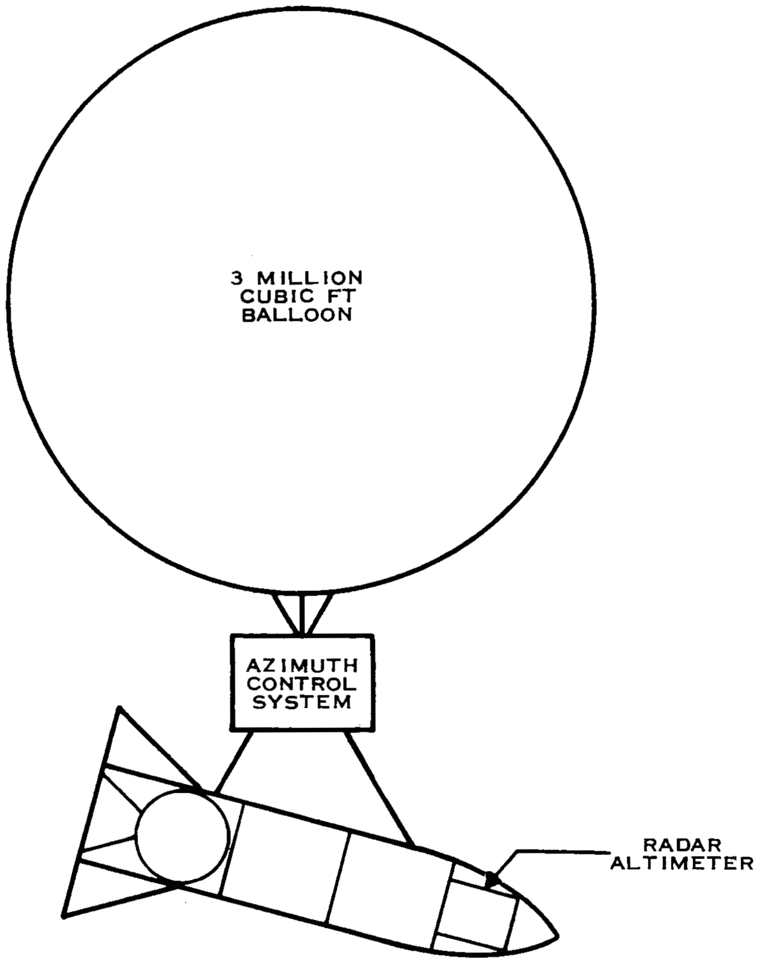

Figure 8. Balloon Configuration

system will be displayed to effect a soft landing. Figures 9 through 14 show the pertinent parameters of a typical entry. The desired velocity altitude conditions are met. Note that immediately following motor burn, a tremendous deceleration of the vehicle would occur due to atmospheric drag. The payload must be stressed to allow for this deceleration which occurs when the most important test data is being collected.

The g loading, as shown on Figure 13, reaches on the order of 100 during the period that the velocity decreases from 10 000 ft/sec to 3000 ft/sec — a time interval of 5 seconds. It should be emphasized that this simulation is more than adequate to prove the structural integrity of the altimeter for a

Mars landing. Using a balloon launch various angles of entry and velocities could be simulated by varying the launch altitude, initial elevation angle of the thrust line, and duration of motor burn in any combination. While this method of test was not the least expensive, it is the simplest and most reliable way of meeting the test objectives.

Launch Site. — The White Sands Missile Range is the launch site for this vehicle since it provides a terrain that most closely simulates the Martian terrain. In addition to having the necessary data reduction capability, as discussed in another section of this report, the balloons may be furnished by Holloman Air Force Base as GSE if it is desired to reduce CFE.

Supporting Payload

The supporting payload equipment provides the support needed to successfully conduct the flight test. The functions of the supporting payload include command and control, attitude monitoring and/or control, power supplies, the recovery system, and telemetry and data handling. The requirements depend on the vehicle and the selected flight test technique. The following discussion is oriented to the recommended flight test system—the balloon launch.

The balloon launch will require a command and control link and an azimuth control unit unique to the characteristic of the balloon launch. The command and control link will provide the monitoring and command capability to launch the vehicle at the desired position and altitude. The azimuth control system will align the vehicle in the desired direction prior to the launch. Status data on the vehicle and the balloon system will be monitored continuously prior to launch. The command link must be a secure system to prevent accidental firing of the vehicle. The azimuth control system can be a simple magnetometer coupled to a gasjet control system.

A recovery system or technique must be provided to recover the payload in case of a balloon failure or the occurrence of other conditions that prevent the vehicle launch.

The vehicle supporting subsystem will contain the functions outlined in the introductory paragraph. The telemetry and data handling equipment will collect, encode (if required), format, and provide the composite data to the transmitter. The output data from the altimeter is a binary word every 500×10^{-6} second. This data will be buffered, reformatted, and used to pulse code modulate the transmitter.

The house keeping and support data can be handled as pcm or fm/fm modulation.

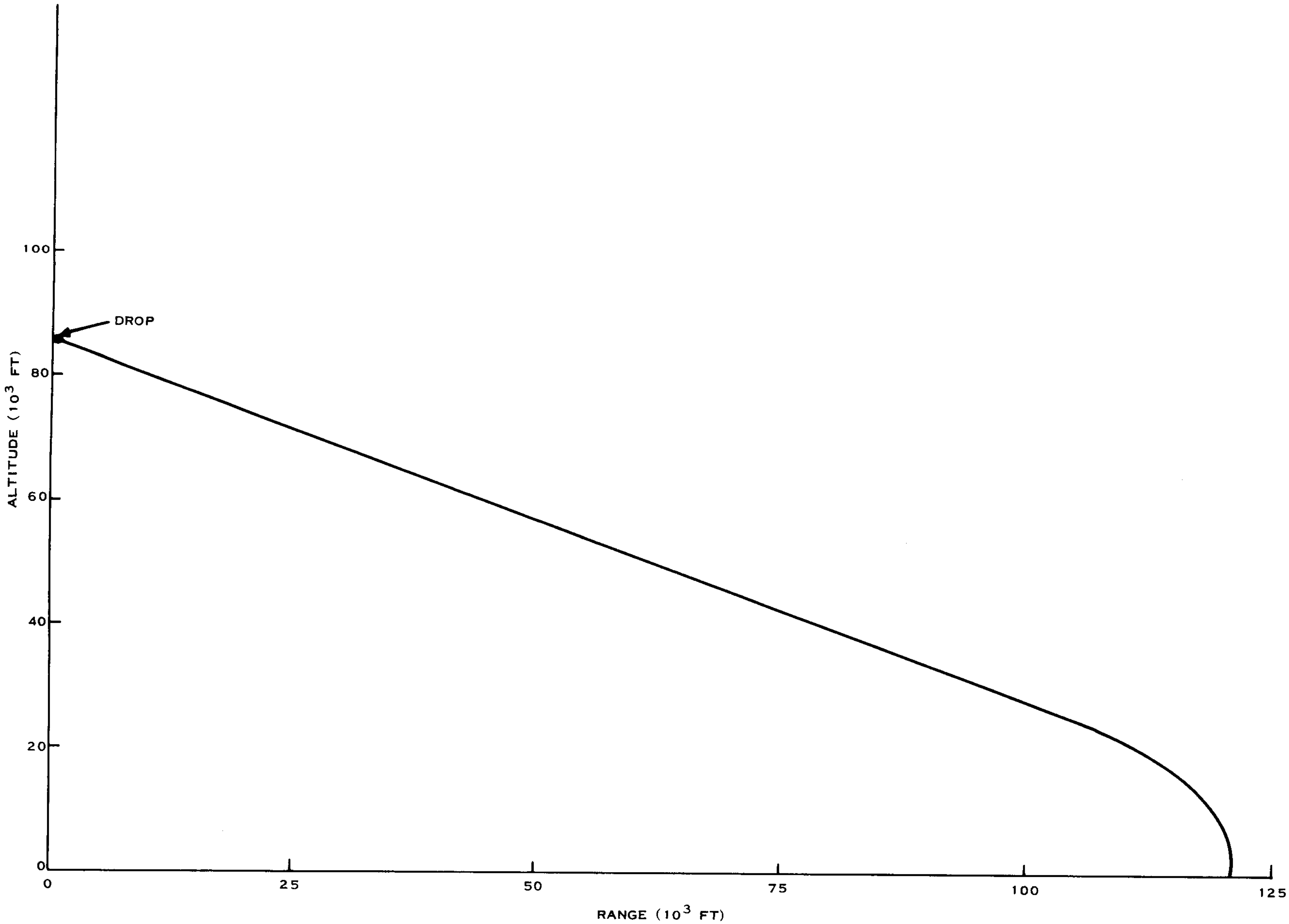

Figure 9. Balloon Drop Altitude Vs Range

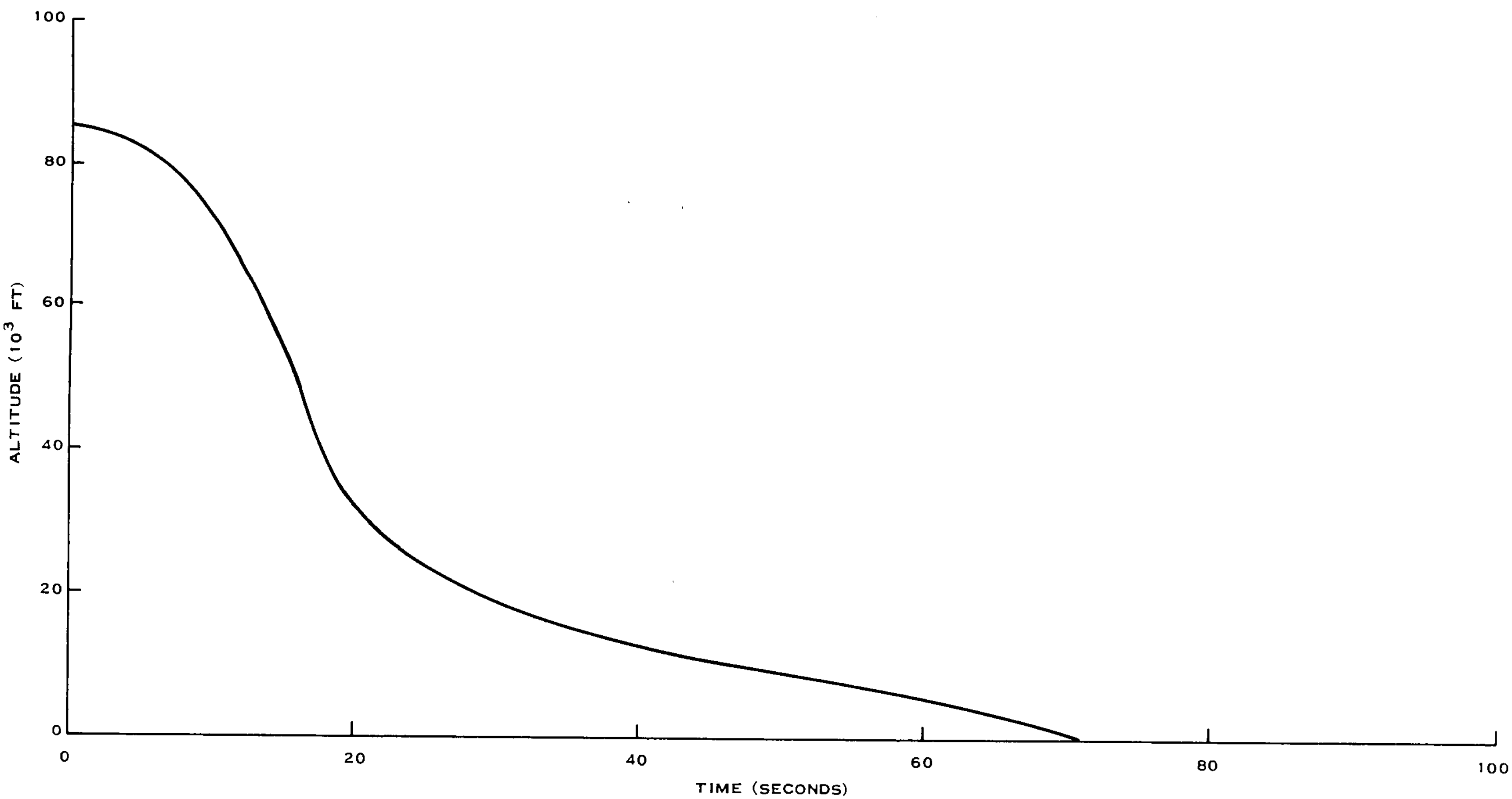

Figure 10. Balloon Drop Altitude Vs Time

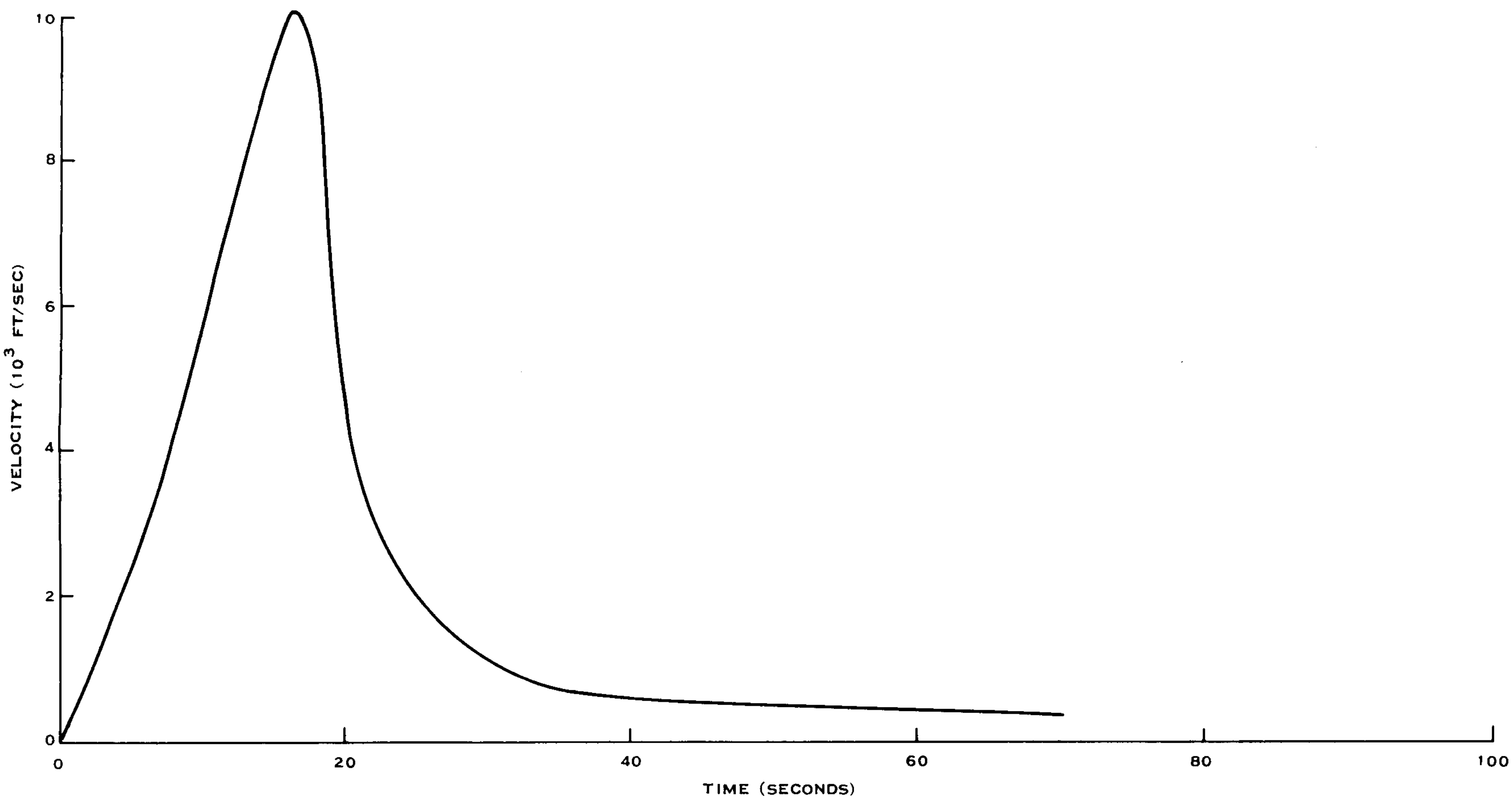

Figure 11. Balloon Drop Velocity Vs Time

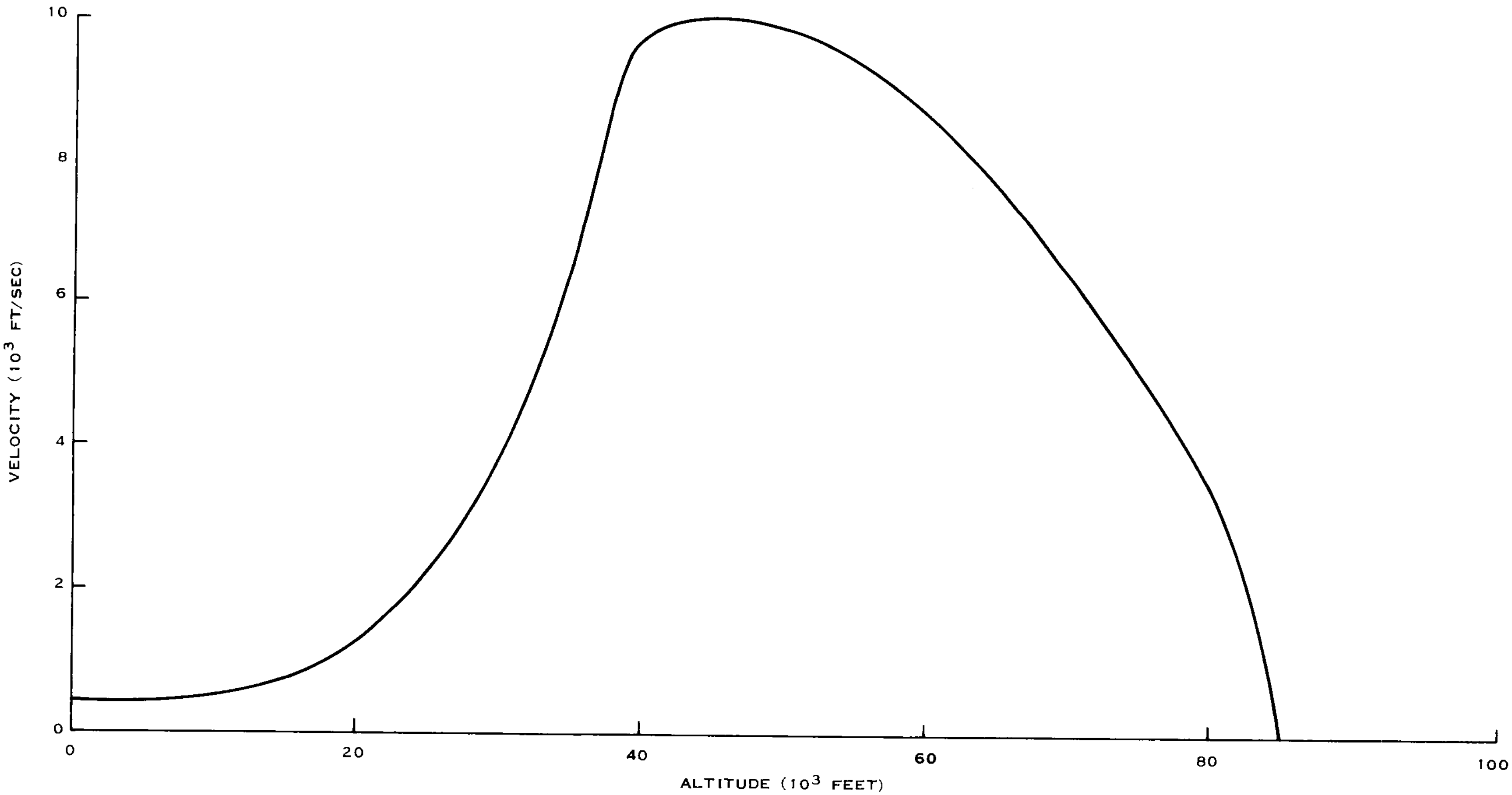

Figure 12. Balloon Drop Velocity Vs Altitude

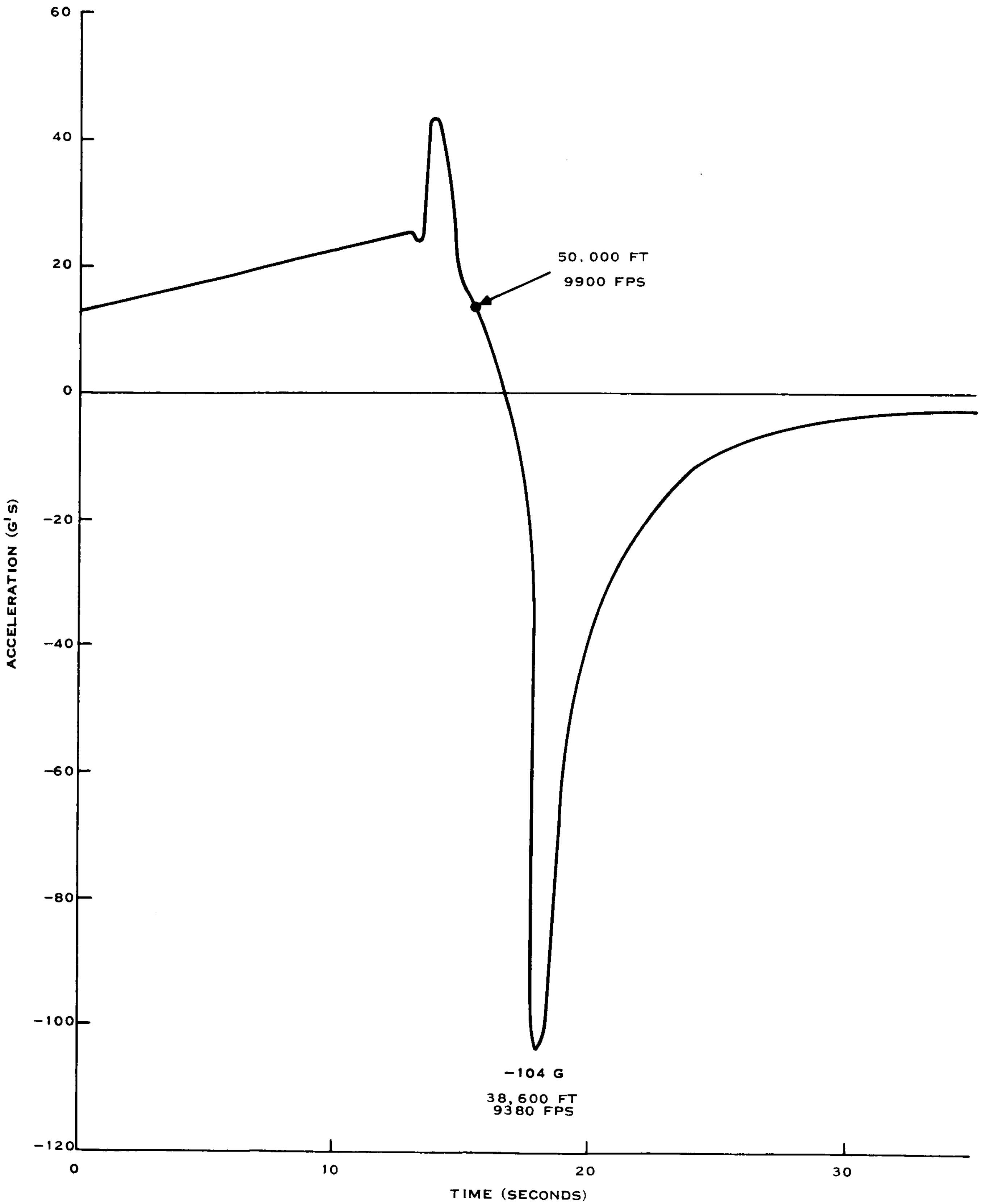

Figure 13. Balloon Drop Acceleration Vs Time

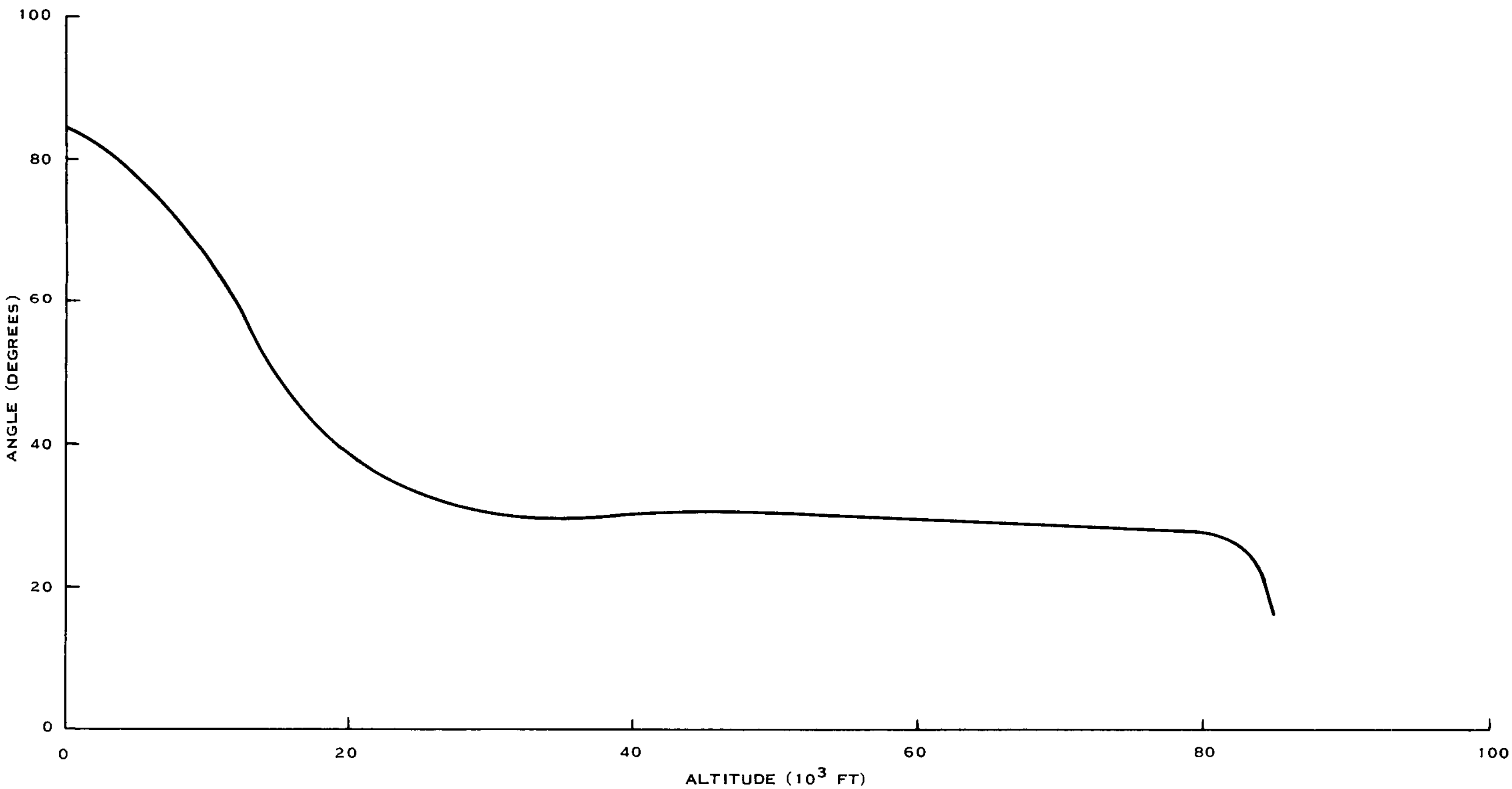

Figure 14. Balloon Drop Angle Between Velocity Vector and Horizontal Vs Altitude

The command and control unit contains the programmer, timer, receiver, and decoder. These functional items provide for all programmed and command control. The ignition command sequence will be designed to prevent accidental or premature ignition of the rocket motor. The command to fire the motor will initiate the programmer which controls the sequence of events from motor ignition to recovery system deployment.

The attitude control and monitoring unit provides information to control the vehicle trajectory and data on the vehicle attitude that may be required to evaluate the performance of the altimeter. The details of the attitude control and monitoring unit will depend on the details of the vehicle implementation. A sun sensor and/or magnetometers can be used to measure payload attitude.

The power source and conditioning for the vehicle will be supplied by silver cadmium battery pack and a converter-regulator system, respectively.

The circuit design effort on the supporting payload equipment will be minimized by designing around existing hardware. The telemetry system will be assembled from off-the-shelf assemblies. A few items, such as the programmer, will require some detail design effort. The design activities on the few special items will be limited primarily to logic design.

Baseline Altitude.— An independent measurement of vehicle altitude as a function of time must be made to provide a baseline for evaluating altimeter performance. The use of range instrumentation to measure the vehicle trajectory and the range data processing capability to compute altitude appears to represent the optimum procedure. The cinetheodolites and radar systems have position accuracies of 5 to 15 feet and 15 to 330 feet, respectively, in the boost phase (above 15 000 feet). The AN/FPS-16 has a maximum slant range of 570 miles. The cinetheodolite has an average maximum operational altitude of 60 000 feet. A combination of the optical and radar range instrumentation should provide data for accurate altitude calculations.

The geodetic services at the WSMR will be required to provide the data to correct for differences in altitude of the range instrumentation and the surface from which the altimeter is operating.

Capability of White Sands Missile Range With Altimeter Test Requirement

The present range telemetry capabilities of WSMR should allow the real-time collection of both altimeter output and status data. The range pcm telemetry capability of 50 kbps is well in excess of the 22 kbps. Altimeter output and commercial fm/fm could be employed for the status channels. This real-time capability should remove any necessity for data storage in the test vehicle. If such an on-board storage system were included as a back-up system, it would consist of a tape recorder with a capacity of 2.5×10^6 bits capable of recording in the vehicles mechanical environment. This recorder would most probably be a modified form of an existing "rocket recorder" designed for this class of operation.

Data Processing. — Determination of the performance of the altimeter could be obtained at the range by comparing the telemetry data to range-supplied tracking data. The required computation could best be done on the data processing equipment available at WSMR, which is set up to process the tracking data inputs. The data processing facilities at WSMR include one IBM 7094, two IBM 7044's, and eight IBM 1401's.

FACILITIES PLAN

Major facilities required for fabricating and testing the radar altimeter are outlined herein. Some of the equipment is available at Texas Instruments, and is identified in table II.

Descriptions of applicable facilities available at Texas Instruments follow.

Flight Tests

Volume 6 of this report lists equipment necessary for a high-speed entry test. Other, much simpler, flight tests can be accomplished using an airplane with a high altitude (at least 50 000 feet) service ceiling. The installation of the altimeter on the plane is easily accomplished at the Apparatus Division Avionics Flight Test Center, which was established in 1959 at Addison Airport, Dallas, Texas. It has complete capability for installing, modifying, and flight testing avionic systems and subsystems of all types. The main paved runway is 4 500 feet long, 100 feet wide, with 1 000 feet of "clear zone." The second or cross-wind runway is 3 200 feet long and 200 feet wide. There are 13 000 square feet of hangar space, 32 000 square feet of ramp space and 8 000 square feet of air-conditioned laboratory space. Facilities include a hydraulic test laboratory and a model shop. Aircraft types which have been modified for various test programs are Convair 240, DC-3, PBIG, L-20, RL-23D, B-25, RF-66, and helicopters. All necessary stress analyses, etc., are performed on each program by engineers located on the site.

Environmental Test

The Apparatus Division environmental test facility is the largest privately owned facility of this type in the southwest. This testing facility can completely simulate the environments in which the division's products will be expected to operate. The laboratory provides facilities to perform tests ranging from a single test of a component to complete military qualifications of entire systems. These facilities are complemented by a staff of engineers and technicians to assist in establishing test methods and preparing test procedures, designing test fixtures and monitoring devices, and conducting actual tests in the laboratory. Complete environmental testing, i.e., temperature-altitude, temperature-vibration, humidity, explosion, sand and dust, salt spray, acceleration, vibration, shock, and RFI, can be conducted.

Electrical Test

The Apparatus Division has some 9 000 items of electrical test equipment in use that are supported by a formal periodic maintenance and calibration procedure. All calibrations are traceable to the Bureau of Standards. All measurement-taking devices for customer acceptance of equipment are certified as to calibration and then sealed to prevent possible tampering by unauthorized persons.

The systems test group, reporting to the Quality Assurance Branch, is responsible for testing all products before delivery to the customer.

Antenna RDT&E Facilities

Texas Instruments maintains a complete company-owned antenna testing facility, located on a 350-acre site adjoining the expressway complex. The facility has three outdoor ranges and a laboratory, which houses two anechoic chambers and a machine shop. In addition to this facility, the company also has a 5 700-foot range in northwest Dallas county.

A 200-foot range and a 400-foot range, located at the expressway facility, are used as pattern and precision boresighting ranges. The other outdoor range has a turntable and is mast-mounted on a movable cart for adjusting the range length to 120 feet. This range is used for most uhf, vhf, and scale-model measurements. The 5 700-foot range, located at North Lake, is used for evaluation of large-aperature antennas.

The anechoic chambers are 11-1/2 feet high, 11 feet wide; one is 32 feet long and the other 20 feet long. The design of these chambers provides at least a —40-dB reflectivity level over a frequency range of 2 to 50 GHz. The usefulness of these chambers for many antenna measurements, however, extends well above and below this frequency range. These chambers are generally used to design frequency-independent antennas and components for microwave antennas.

All the ranges are equipped with either Scientific Atlanta or Antlab recording equipment. This equipment includes rotators and pattern recorders which may be switched to either a polar or rectangular chart. In addition, three super-heterodyne receivers and one pattern integrator are available and may be used on any range.

The facility is equipped with power, impedance, frequency, and attenuation equipment that covers the frequency bands from 10 MHz to 35 GHz. However, radiation pattern measurements are generally made from 15 MHz to 35 GHz.

These facilities are complemented by a staff of engineers and technicians to assist in establishing test methods and preparing test procedures, designing test fixtures, and conducting actual tests on the ranges.

Fabrication Facilities

The component fabrication shops are composed of mechanical model shop, tool shop, short-run machine shop, production machine shop, sheet-metal shop, etched circuit board shop, heavy fabrication shop, and metal finish shop. The mechanical model shop provides a service to engineering, in development and prototype work for mechanical components and systems. The tool shop makes tools, dies, jigs, and fixtures for use in the other fabrication shops. The short-run machine shop is used for limited-quantity production. The sheet-metal shop fabricates all sheet-metal components and assemblies and has a separate facility for fabrication of electronic equipment cabinets up to 24 by 48 by 84 inches. The etched circuit board shop has facilities for making circuit boards from clad laminates. The heavy fabrication shop has facilities for working and welding materials ranging from very small, thin sections of aluminum, magnesium, stainless steel, copper, and nickel alloys to all-aluminum radar reflectors 9 feet by 18 feet. The metal finish shop does plating and surface treatment of metals, painting, and symbolization by silk screening, stamping, decals, and other methods as required.

Cleanroom Facilities

A large cleanroom is available at Texas Instruments for manufacturing assembly operations, requiring a high degree of contamination control. This room is a laminar cross-flow type with 3600 square feet of working area and a 400-square-foot anteroom for material preparation and cleaning operations. Room environment exceeds the requirements of Federal Standard 209, and any desired class of air cleanliness prescribed in the standard can be obtained. Room conditions are automatically controlled for temperature, humidity, and positive pressure. Monitoring instruments provide continuous records of temperature, humidity, and particle count. This cleanroom is the largest and finest of its type in existence. Its design and construction have been highly recommended by Mr. W. J. Whitfield of Sandia Corporation, a recognized authority on cleanroom technology, who was instrumental in preparation of Federal Standard 209.

Detailed specifications of the cleanroom are:

General:

Type	Laminar crossflow
Area	3600-square-foot working area 400-square-foot anteroom
Applicable Government Specifications	Exceeds requirements of Federal Standard No. 209, Class 100, 000; Air Force Technical Order 00-25, Revision 1, July 1963

Environment Control Capabilities:

Temperature	68° to 78°F ±1.5°F
Relative Humidity	30 ±3 percent
Air Pressure	Positive, nominal 0.22 inch H_2O; minimum on door opening 0.08 inch H_2O
Air Velocity	Uniformly 100 ±10 feet per minute
Change Cycle	40 seconds
Replacement Cycle	200 seconds
Makeup Air	1000 to 5000 cubic feet per minute as required
Particle Control (0.5 micron or larger)	Room empty—less than 200 per cubic foot Room operating—less than 100, 000 per cubic foot

Mechanization	
Temperature Control	Hot water coils, flow modulated 30-ton capacity chilled water coil 10-ton capacity direct expansion
Humidity Control	Walton atomizing humidifier in air supply duct
Pressure Control	Vane modulated blower on input side of air handling unit, 1000 to 5000 cfm capacity
Control Actuation	Fast response pneumatic motors
Instrumentation	
Temperature and Humidity	Brown Instruments 24-hour recording indicator
Pressure	Cambridge Manometer Type 6A25
Particle Count	Rayco Particle Counter with continuous tape printout
Air Filtering	
Air Handling Unit	1-inch fiberglass prefilters 2-inch metal filter mats on discharge side
Room Filter Bank	1-inch fiberglass prefilters on blower input 6-inch Cambridge absolute HEPA mechanical filters.

Assembly Facilities

The electrical assembly shop occupies 53 000 square feet of plant area and accommodates approximately 675 work stations. The cleanroom facility described herein, supports the other assembly facilities with approximately 65 work stations.

Conventional bench soldering and flow soldering are done to all military specifications, to NASA specifications requiring Government certified operators and instructors, and to Jet Propulsion Laboratory's standards for spacecraft equipment. The welding assembly group has both crosswire welders and parallel-gap welders. The latter technique has been pioneered by Texas Instruments and these machines are now being manufactured and marketed by Texas Instruments.

Table 2. Facilities

Operation	Facility Availability
Development	
Antenna (Patterns, etc.)	Texas Instruments
Sterilization Effects	
Heat Soak	Texas Instruments
Surface	Government
Breadboard Evaluation	Texas Instruments
Testing	
Formal Electrical Tests	Texas Instruments
Environmental Tests	
Shock	Texas Instruments
Vibration-simple wave	Texas Instruments
Vibration-complex wave	Government
Explosive Atmosphere	Texas Instruments
Humidity	Texas Instruments
RFI	Texas Instruments
Thermal-Vacuum	Government
Systems Tests	Government
Life Test	Government
Flight Tests	
Installation	Texas Instruments
High Altitude Plane	Government
High velocity entry (See Volume 6)	Texas Instruments or Government
Monitoring	Government
Fabrication	
Clean Room	Texas Instruments
Shops	Texas Instruments

PROJECT FUNDING PLAN

A budgetary estimate of the cost of developing, testing, and delivering a maximum quantity of ten radar altimeters has been made. The major items are:

1. Development—Includes one breadboard, one engineering model, and two prototype models (one backup) for testing purposes. Environmental and reliability tests are included in the cost estimating.

2. Flight Tests—Includes both aircraft and high velocity rocket tests.

3. Production Lot I—Includes fabricating and delivery of two (2) altimeters.

4. Production Lot II—Includes fabricating and delivering eight (8) altimeters.

5. Mission Support—Includes monitoring tests performed by NASA of altimeter and lander; preflight tests, and post flight analyses.

6. Documentation—Includes cost of writing and printing any formal documents (test results, periodic reports, etc.).

Figure 15 shows the approximate percentage cost of each item, Figure 16 shows the expected percentage of expenditures versus time, and Figure 17 shows the approximate expenditure for each six month period.

Costs were estimated for a program start date of July 1967, and were broken into six month periods.

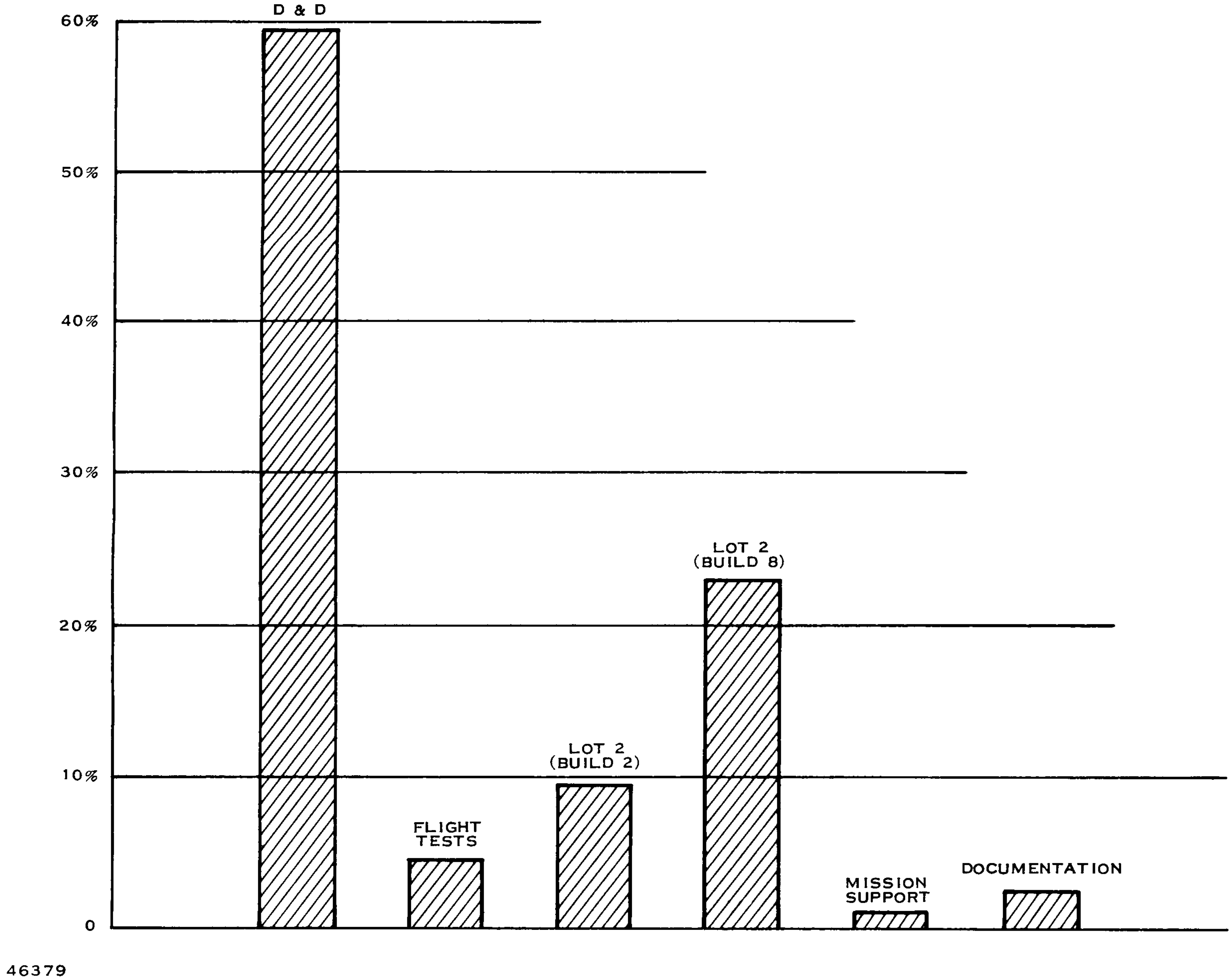

Figure 15. Percentage Cost per Item

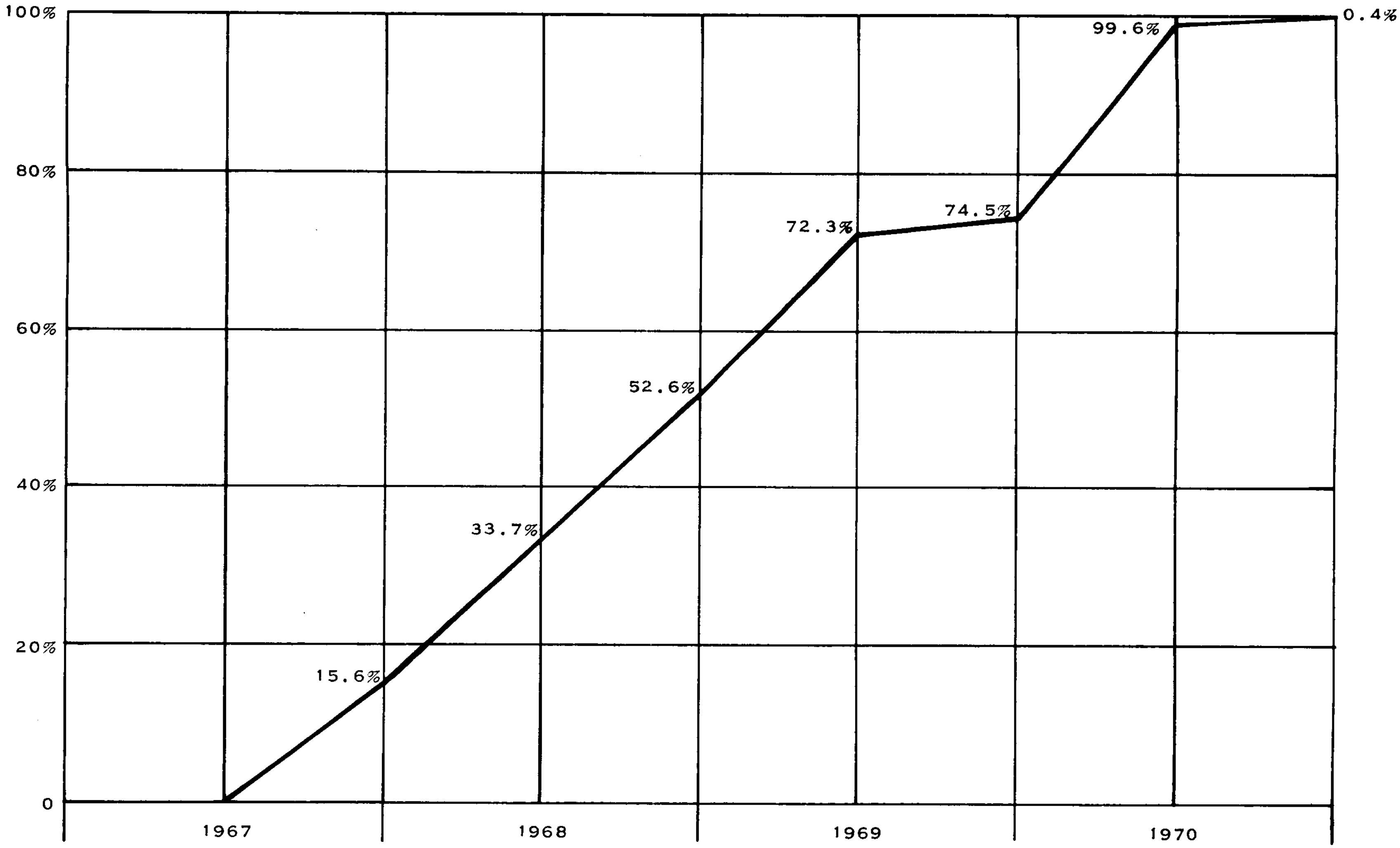

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Figure 16. Cumulative Cost per Six Month Period

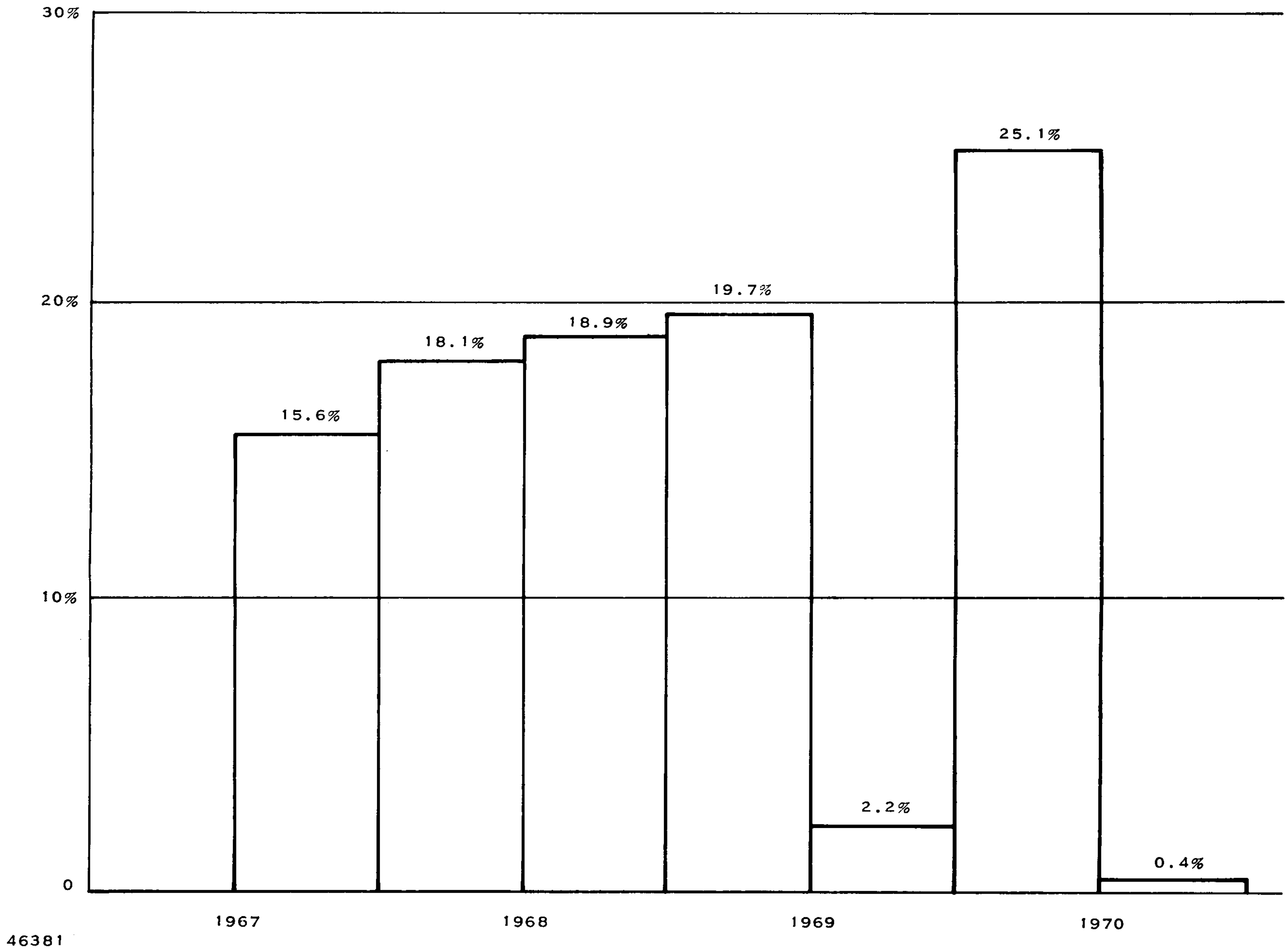

Figure 17. Percentage Cost per Six Month Period

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2. JPL Project Document 92, Mariner Mars 1969 Spacecraft System Environmental Estimates (Preliminary Issue).

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